California ISO

WHITE PAPER

High Sustainable Limit (HSL)

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Revision History

Date	Version	Description	Author
8/7/2020	1	Initial posting of document	Jessica Taheri

Table of Contents

Background

As of August 1, 2020, there are over 19,700 MW of grid-connected variable energy resources (VERs) on the CAISO system.[1] Accurately forecasting the output of these VERs is increasingly critical to grid operations. Currently, the CAISO requires each resource to provide real-time telemetry and meteorological station information to create the highest quality forecast.[2] As market participants add batteries to these variable resources (under either a Hybrid or Co-Located configuration), having visibility to the VER components production capability based on fuel availability (wind or sun) during all intervals of the day will become more crucial to allow these resources to offer Ancillary Services (AS) and ensure the CAISO is able to provide the most accurate forecast possible under these new configurations. Given this need, the CAISO is proposing that the variable energy components of Hybrid and Co-Located Resources provide their High Sustainable Limit (HSL) as a telemetered value to the CAISO.[3]

The below three terms will be used throughout the White Paper and additional details can be found in the Revised Draft Tariff Language of the Hybrid Resources Initiative, but are repeated below: [4]

Hybrid Resource: A Generating Facility, operated as a single Resource ID at a single Point of Interconnection, whose component Generating Units use different fuel sources or technologies

Co-Located Resource: A Generating Unit with a unique Resource ID that is part of a Generating Facility with other Generating Units. An EIM Participating Resource with a unique Resource ID that is part of a single resource with other EIM Participating Resources.

The CAISO proposes to define High Sustainable Limit as follows:

High Sustainable Limit (HSL): The instantaneous generating capability of a variable or intermittent Generating Unit or component thereof, updated through telemetry at the Generating Unit every five minutes. The High Sustainable Limit may not exceed the Generating Unit's PMax.

The HSL is a real-time estimate of the maximum output capability of a VER resource or the VER component of a Hybrid or Co-Located resource based solely on the resource's physical properties (*i.e.* number of solar panels or wind turbines, and available inverters) and the fuel available to the resource based on current weather conditions. The HSL will be sent to the CAISO as a calculated, telemetered value and represents the approximate energy output capability of the resource at that moment in time.

[1] http://www.caiso.com/informed/Pages/CleanGrid/default.aspx
[2] See Appendix Q of the CAISO Tariff for specific requirements
[3] The HSL was first identified as a need for Hybrid and Co-Located VERs in the Straw Proposal for the Hybrid Resources Initiative issued on October 3, 2019. In this Straw Proposal, it was first identified as "Plant Potential" but was updated to be referred to as the "High Sustainable Limit" in the Revised Straw Proposal issued on December 17, 2019.
[4] http://www.caiso.com/InitiativeDocuments/RevisedDraftTariffLanguage-HybridResourcesPhase1.docx

It is a calculated estimate; not a forecast. For instance, a resource's HSL sent as a telemetry to the CAISO at 10:00 PPT represents that resource's High Sustainable Limit at 10:00 PPT; it is not a forecast of the resource's capability at a future point in time.

The Electric Reliability Coordinator of Texas (ERCOT) has a similar value they require for all of their generation resources, called the High Sustained Limit. ERCOT defines the High Sustained Limit for a Generation Resource as

> *The limit established by the QSE [Qualified Scheduling Entity], continuously updated in Real-Time, that describes the maximum sustained energy production capability of the Resource*[5]

and continue on in their Nodal Protocols (similar to CAISO's BPM)

> *For each Intermittent Renewable Resource (IRR), the QSE shall set the HSL [High Sustained Limit] equal to the current net output capability of the facility. The net output capability should consider the net real power of the IRR generation equipment, IRR generation equipment availability, weather conditions, and whether the IRR net output is being affected by compliance with a SCED [Security Constrained Economic Dispatch] Dispatch Instruction.*[6]

The definition proposed by CAISO and the definition currently in effect in ERCOT's market are very similar. Both indicate that they are continuously updated in real time and express the physical generating capability of the resource at that time. Within ERCOT, the High Sustained Limit is considered a telemetry point and is a required input into their real-time sequence.[7]

At this time, the CAISO proposes that the HSL be required for Co-Located Resources and Hybrid Resources with a VER component. In the future, as VER resources are further offered and optimized in the market for Ancillary Services, including regulation, and supplemental dispatch, the CAISO does anticipate a business need for HSL to be required from VER resources. Discussions regarding requiring the HSL from VER resources (other than Hybrid or Co-Located) will be done in a future Stakeholder Initiative.

HSL Compared to Current Telemetry

The HSL is different than the current MW telemetry provided to the CAISO by current VER resources. For current VER resources, the MW telemetry value reflects actual supplemental dispatches, operating instructions, ancillary services and when applicable, losses. For Hybrid resources, the MW telemetry will also be impacted by the battery charging and discharging. Again, the HSL is not impacted by any market actions listed above, including battery charging or discharging, since it is simply an estimate of the VERs physical capability given fuel availability and current weather conditions. The HSL will allow the CAISO to get a full picture of the maximum available output a VER resource or the VER component of a resource given current properties and weather conditions.

[5] http://www.ercot.com/glossary/h
[6] http://www.ercot.com/content/wcm/current_guides/53528/06-070120_Nodal.docx
[7] http://www.ercot.com/content/wcm/current_guides/53528/06-070120_Nodal.docx

Figure 1 shows the difference in a solar resources MW telemetry currently provided to the CAISO, and the HSL on a day with heavy supplemental dispatch. The impact shown below on current MW telemetry due to supplemental dispatch would be a similar impact as charging a battery. The HSL value is not impacted by the changes in the resources output due to supplemental dispatch values, nor would it be impacted by charging or discharging a battery, only changes in the fuel availability, *i.e.* weather.

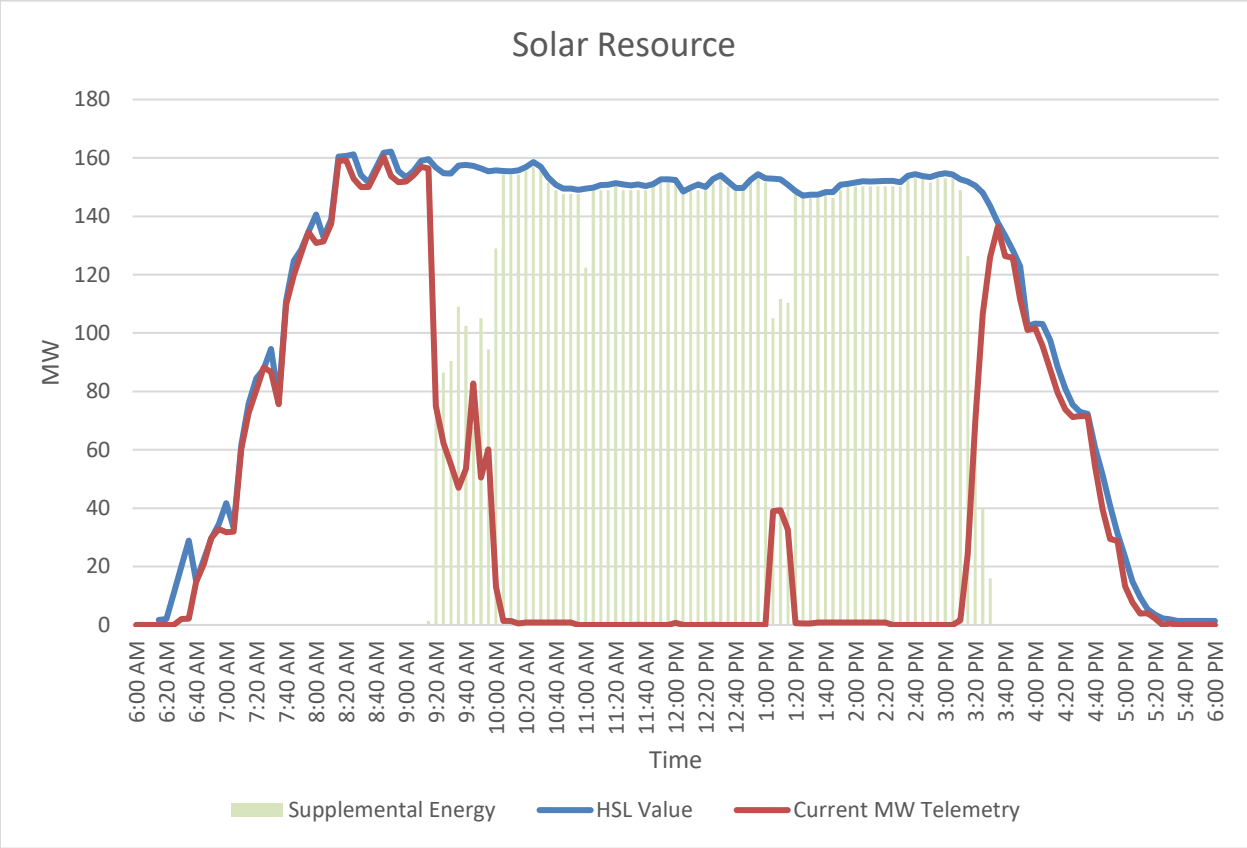

Figure 1: Comparing the HSL value to the current telemetry value received by the ISO for a solar resource during daylight hours.

Currently, with only the MW telemetry data provided to the CAISO by the resource, there is a large portion of the day where these values have been impacted by supplemental dispatch and cannot be used in forecast creation. The CAISO can theoretically add supplemental dispatch back into the MW telemetry information to get an approximation of the resources production capability; however, the value calculated may not always be correct, especially the longer supplemental dispatch goes on. This is shown in Figure 2 which compares the HSL value to the current MW telemetry plus supplemental dispatch added back. In addition, if a resource is not following their DOT exactly, this approximated estimate of production capability would be incorrect.

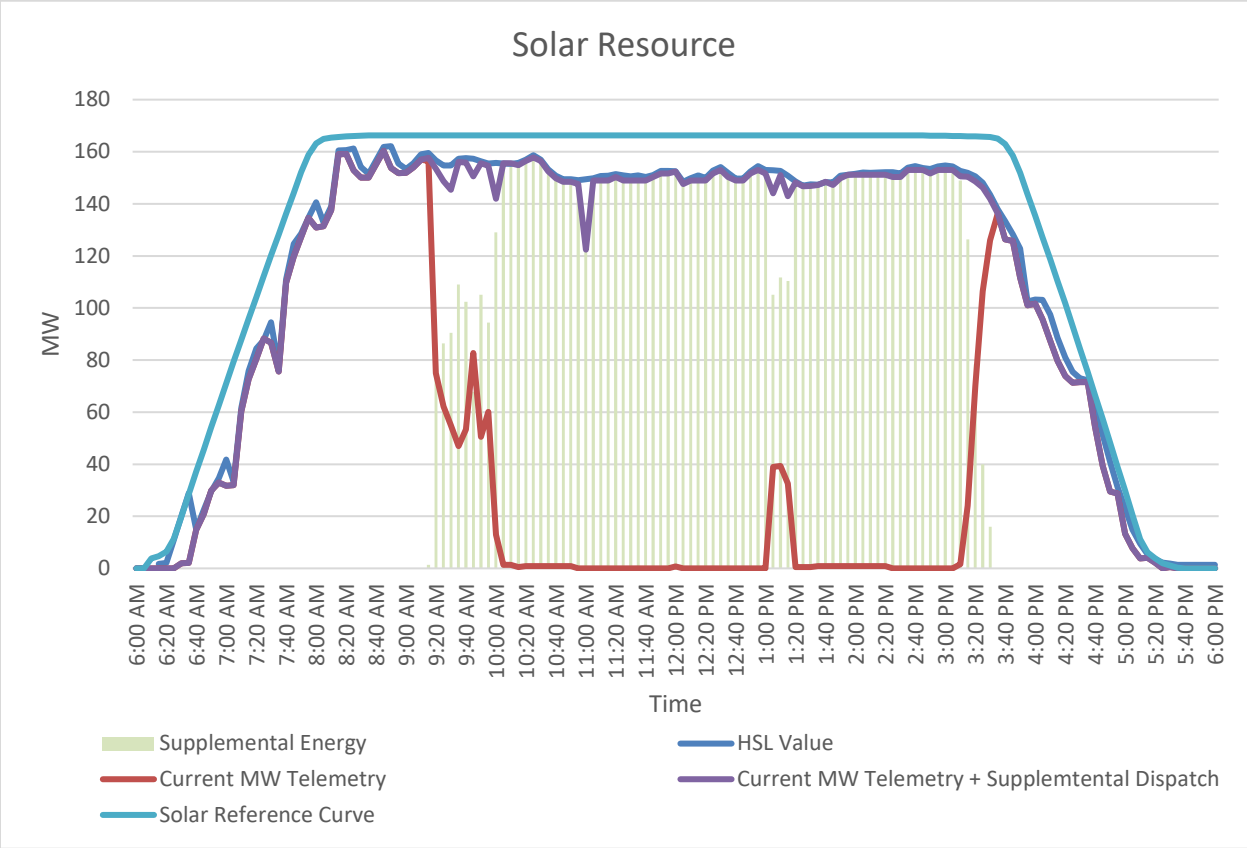

Figure 2: Comparing the HSL value, to the current MW telemetry the ISO receives, the solar reference curve and the current MW telemetry + supplemental dispatch. The purpose of adding supplemental dispatch into the current MW telemetry is described below.

Conversely, the HSL information for this day in Figure 2 provides a more informed capability of the resource and could have been used to inform the real-time forecasts. The HSL telemetry will be available for the CAISO's forecast providers in real-time to use in their forecast creation. This will lead to a more accurate representation of what the resource could be producing feeding into the model. Additional information on this is below in the Business Needs section.

Figure 2 also includes the resources' solar reference curve, showing the maximum generation capability for this resource on this given day of the year given the sun angle and length of day. The solar reference curve does not take into account current weather conditions for that specific day.

Business Need

The HSL telemetry will be primarily used for forecasting needs, but is also going to be indirectly used to assist with renewable resources that are providing AS, including regulation, in addition to assessing the capability of a Hybrid Resource and for operational awareness.

Forecasting

From the forecasting perspective, the HSL data will be sent to forecast providers to supply them with the generating capability of the VER component of a resource. Currently, when the MW telemetry is impacted by supplemental dispatch or operating instructions, this data cannot be used to create the real-time forecast. Instead, vendors must rely only on the meteorological station information and/or characteristics of the resource, *i.e.* location and panel characteristics for solar or turbine information for wind. The HSL data will allow the real-time forecast to continue to have an approximate weather-based MW capability as an input during periods of battery charging/discharging, supplemental dispatch, AS or operating instructions, instead of having to ignore the MW telemetry, like is currently done. In addition to improving the real-time forecast methodologies, the CAISO anticipates the use of HSL will improve the fifteen minute market (FMM) and day ahead (DA) forecasts as well, due to a significant increase the amount of good data to use in the forecast training for all forecast horizons.

As described in the previous section, for periods of supplemental dispatch, the CAISO and forecast vendors can add the supplemental dispatch information to the MW telemetry to get an estimate of the resources total capability, but this is not always accurate. By providing the HSL to the CAISO's forecast vendors, the forecast creation can use the HSL for every interval of the day regardless of whether or not there is any market dispatch present, to better inform the forecast.

The HSL telemetry could also be used to feed the Persistence forecast[8]. The Persistence forecast is internal to the CAISO and heavily weights the MW telemetry from a VER resource to create the forecast used in real-time dispatch (RTD). Currently, the Persistence method uses the MW telemetry data coming from the resource as input. When this MW telemetry is impacted by a market dispatch (such as supplemental dispatch), then the external forecast is used for those intervals instead. It has been shown that the Persistence methodology has up to a 45% improvement on RTD forecast accuracy over the external forecast provider[9]. In the future, the CAISO is hoping to use the HSL information to feed the Persistence forecast instead of the MW telemetry. This will allow for the Persistence forecast to be used for all intervals, regardless of battery or market impacts for a VER resource or VER component of a Hybrid or Co-Located resource.

Figure 3 below compares forecast creation methodologies with and without the HSL as forecast input on a day with an Operating Instruction (OI) for a wind resource. The OI was in place from 0800-1700 (0900 – 1800 on the graph below) and during this period VER resources were instructed not to exceed their dispatch operating target (DOT). For this resource, the DOT was equal to the forecast as there was no supplemental dispatch present. The "Current Forecast" line below is created using the external forecast while the "Persistence Forecast Created Using HSL" uses the HSL value as input to create the Persistence Forecast instead of the MW telemetry, as is normally done.

[8] http://www.caiso.com/Documents/Presentation-MarketPerformance-PlanningForum-Oct242018.pdf
[9] http://www.caiso.com/Documents/AgendaPresentation-MarketPerformancePlanningForum-Jun11_2018.pdf

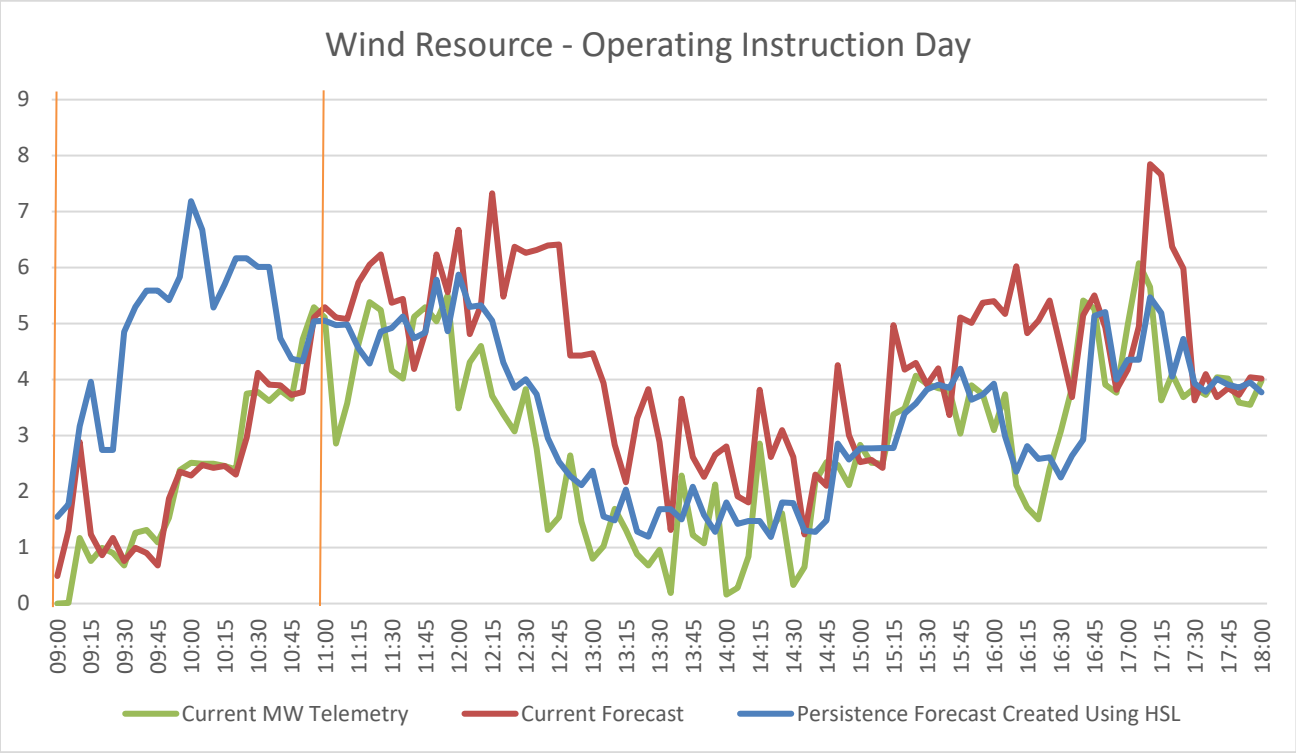

Figure 3: Comparing a wind resources forecast using current methodologies to the forecast created using HSL data on a day with an Operating Instruction

For the duration of the OI, the resource's MW telemetry cannot exceed the RTD forecast (DOT). During the period of 09:00-11:00 (denoted by the orange lines), the MW telemetry is limited on the upper-end by the forecast; however, had the resources HSL been available to the CAISO and used to produce the RTD forecast during this time, the forecast would have been higher and likely more representative of the capability of the resource. This is because the HSL telemetry and, thus HSL Persistence Forecast, is not impacted by the OI, only by the current weather conditions.

For the period of 11:00-18:00 in Figure 3, again the MW telemetry cannot exceed the forecast; however, in this instance the forecast is consistently too high, leading to increased forecast error. Comparing the two forecasts methodologies to the MW telemetry coming from the resource, the Persistence forecast created using the HSL is closer to the output of the resource, whereas the external forecast was consistently too high. Using the HSL as input to the Persistence forecast on this day would have led to 50% increased forecast accuracy during the entire OI and a 65% improvement in the forecast from 11:00-18:00.

In addition to OI periods, the HSL also has benefit in feeding the Persistence forecast during periods where there is a MW telemetry issue. Figure 4 below shows the Persistence forecast created using the current methodology of using the MW telemetry, which was in error, and the Persistence forecast created using the HSL telemetry as input. The CAISO does have checks to remove the Persistence method in RTD if the entire remote intelligent gateway (RIG) is down; however if only the MW telemetry

point is down, like below, then it's possible the MW telemetry value experiencing an error is used to create the Persistence forecast in RTD. Potentially, the HSL can be used as the primary forecast input to Persistence for all resources across all days. In this type of situation with a telemetry error, the Persistence forecast using the HSL as input would have led to a higher forecast value, likely more representative of what the resource would have been able to produce given weather conditions.

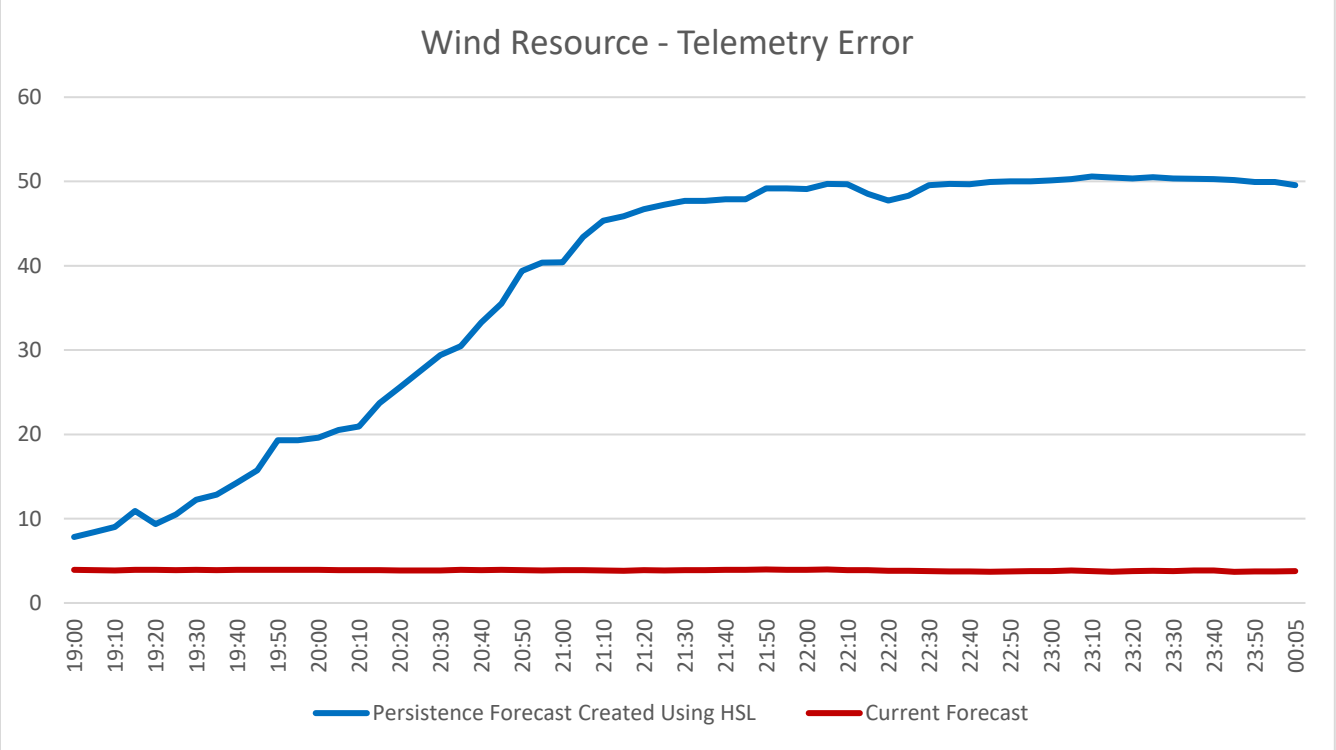

Figure 4: Comparing a wind resources forecasting using the current Persistence forecast methodology and using the Persistence forecast fed by the HSL data during a period of data quality issues.

Ancillary Services

Ancillary Services (AS) refers to Regulation[10], Spinning Reserve, Non-Spinning Reserve, and Voltage Support with such other interconnected operation services as the CAISO may develop in cooperation with Market Participants to support the transmission of Energy from Generation resources to Loads while maintaining reliable operation of the CAISO Controlled Grid.[11]

[10] The service provided either by resources certified by the CAISO as equipped and capable of responding to the CAISO's direct digital control signals, or by System Resources that have been certified by the CAISO as capable of delivering such service to the CAISO Balancing Authority Area, in an upward and downward direction to match, on a Real-Time basis, Demand and resources, consistent with established NERC and WECC reliability standards and any requirements of the NRC. Regulation includes both an increase in Energy production by a resource or decrease in Energy consumption by a resource (Regulation Up) and a decrease in Energy production by a resource or increase in Energy consumption by a resource (Regulation Down).

[11] http://www.caiso.com/Documents/AppendixA-MasterDefinitionSupplement-Jul1-2020.pdf

In the current CAISO system there is no way to send AS information for VER resources when they are being dispatched for AS, including regulation, to our forecast providers. Without HSL telemetry, in order for the forecast providers to have all of the necessary information to create a fully informed VER forecast including AS awards and dispatches, the CAISO would also have to send regulation up cleared, regulation up dispatched, regulation down cleared and regulation down dispatched, in addition to telemetry and supplemental dispatch information already sent.[12] This information would need to be transmitted every 5-minutes for every VER. Increasing the amount of data sent, as well as the additional time and processing power it would take to correctly incorporate all of this information into the forecast, would likely add additional lag time between the forecast providers receiving the data and when the market forecast can react. See Table 1 below for an example of how the current MW telemetry and HSL would be impacted by an AS award.

The HSL will only require one additional point be sent to forecast vendors, instead of four additional, and will provide a consistent flow of the resources capabilities. This will allow there to be good data for all intervals, regardless of the AS award or dispatch and will allow for improved forecasting methodologies as a result. The CAISO expects the number of VER resources providing AS, as well as the number of intervals each resource provides AS to increase in the coming years, especially with batteries attached, and by providing the HSL to our vendors, this will limit the amount of data impacted by AS awards and dispatches.

Data Point (MW)	Hour 12	Hour 13	Hour 14
Forecast	500	500	500
AS Regulation Up Cleared	100	100	100
DOT	400	450	500
MW Telemetry	400	450	500
AS Regulation Up Dispatched	--	50	100
HSL	500	500	500

Table 1: How the MW telemetry and HSL will be impacted by AS awards. AS Regulation Up Cleared and AS Regulation Up Dispatched are additional points The CAISO would need to provide to forecast providers to obtain the same information that HSL could supply in one point.

In addition, by receiving the HSL data the CAISO is able to confirm that the VER resource is able to produce any necessary energy when an AS award is given.

Technical Specifications

How HSL is Determined

HSL is a calculated value that comes directly from the site. When there is no supplemental dispatch or AS in place, the HSL is the generation capacity. When there is supplemental dispatch in place, the HSL is the generation capacity without the supplemental dispatch or AS signal. The generation capacity is calculated based upon known weather information and characteristics of the resource, such as: wind

[12] See Appendix A of the CAISO Tariff for definitions of Regulation Up and Regulation Down

speed, wind direction and number of turbines for wind resources, and solar irradiance and available inverters from a solar resource. This information can be applied to a known power curve for the site to determine the sites generation capacity.

Resource Updates to Provide HSL

As long as the site has an existing telemetry point communicating with the CAISO, the only potential enhancements to the site would be on the software side. In discussions with renewable builders, it was communicated to the CAISO that the cost would be minimal to provide the HSL information as it does not require installation of new equipment.

Reporting HSL to the CAISO

HSL will be reported in the same manner as current MW telemetry and meteorological station information is reported. The CAISO would like the HSL information transmitted as quickly as possible to minimize the amount of lag in forecast processes. It has been shown that HSL can be sent as frequent as 10-seconds. The CAISO is proposing the HSL be sent at a 10-second frequency. Each VER component of a Hybrid Resource must provide their own HSL value, just as they will be expected to provide their own MW telemetry and meteorological information. The resource owners SCADA team would need to collaborate with the CAISO to add HSL as a data point coming from the resource.

Stakeholder Questions

The majority of questions asked in response to the Hybrid Resource Initiative Stakeholder Meeting and Second Revised Draft Proposal have been answered in previous sections.[13] There were additional questions that we wanted to provide answers for, which are below.

HSL versus Other Points

What is the difference in meaning and calculation between HSL, dynamic limit and aggregate capability constraint?

Dynamic Limit

For current, stand-alone VER resources, the CAISO derives an upper dynamic limit strictly from the forecast generation. For Hybrid Resources, it will be based on the value submitted to the ISO from the Hybrid Resource scheduling coordinator (SC), which will be the total forecasted output of the Hybrid Resource. These values will limit the dispatch instruction for the Hybrid Resource in the positive or negative direction. The dynamic limit tool will be the tool available to scheduling coordinators to ensure that Hybrid Resources do not get scheduled for an infeasible dispatch, based on potential state of charge conditions, renewable availability, internal storage charging schedules, etc. The dynamic limit value will be based off the total output expected by the Hybrid Resource, whereas the HSL value is the maximum output of only the VER component of the Hybrid Resource. The HSL is a telemetry used to

[13] https://stakeholdercenter.caiso.com/StakeholderInitiatives/Hybrid-resources

inform the forecast sent to the SC to create their forecast for the full Hybrid Resource, as it itself is not a forecast.

Aggregate Capability Constraint

Using the aggregate capacity constraint functionality, the CAISO will have the ability to issue market awards and dispatches from co-Located resources to ensure the combined PMax of co-located resources associated with a single generating facility does not exceed the interconnection service capacity of that generating facility. Interconnection customers electing to use the aggregate capability constraint will allow co-located resources to register their maximum operating limit as their PMax, even if the aggregate values of these maximum operating limits are greater than interconnection rights set forth in their generating facility's generator interconnection agreements.

The HSL is not the amount of energy the VER resource is actually putting onto the grid, rather it is the maximum generating capacity of the VER resource. It is possible for this maximum generating capacity to be higher than the interconnection service capacity at the point of interconnection (POI) if the VER resources PMax is higher than the POI (see Overbuilt Resources below for additional details). HSL is a telemetry point from the VER resource sent to the CAISO to inform the forecast.

Overbuilt Resources

How would an overbuilt resource (build in excess of the POI limit to charge the storage) report its HSL?

An overbuilt resource refers to a resource that have built more MW than they were studied for in the generator interconnection process as the Net MW at the POI. These resources are either a Hybrid Resource or Co-Located Resource, who's solar or wind component was built with additional generation capacity such that the VER is capable of generating more energy than the POI limit provided to the CAISO. For example, a resource with a 150 MW solar component and a 50 MW battery, but the Net MW at the POI is 100 MW. A resource may do this to use the additional 50 MW of solar production to charge the battery on a sunny day or to have additional MW to assist in providing the full 100 MW capability on a cloudy day without having to lean on the battery.

For these cases, the HSL would be reported as the maximum amount of generation that the VER resource would be able to produce without the POI limitation. Meaning if the generating capability of a solar resource is 150 MW and the Net MW at the POI is 100 MW, the HSL would be 150 MW as this is what the VER component is able to produce. For Hybrid resources, the forecast sent to the SC will be for the full renewable component. The below tables provide examples of how the HSL would be reported for a 150 MW solar resource with a 50 MW battery and a 100 MW POI.

Solar (MW)	Battery Charging (MW)	Net at POI (MW)	HSL (MW)
150	50	100	150

Solar (MW)	Battery Charging (MW)	Net at POI (MW)	HSL (MW)
120	50	70	120

Table 2: Showing the HSL value reported to the ISO for an overbuilt Hybrid resource.

Legacy VER resources

How will the CAISO deal with the HSL and legacy wind turbines or solar resources?

As long as the site has an existing telemetry feed to the CAISO, HSL can be added. The information required for legacy resources to calculate the HSL is the same as described above in the "How is the HSL determined" section and includes: total site MW generation, wind speed and number of turbines online if a wind site and solar irradiance and number of inverters available if solar. As mentioned above, discussions regarding requiring the HSL from VER resources other than Hybrid or Co-Located, including legacy VERs, will be done in a future Stakeholder Initiative.